MARSHALL MIX DESIGN METHOD FOR ASPHALTIC CONCRETE (ASPHALT-RUBBER) [AR-AC]

(An Arizona Method)

SCOPE

1.   (a)   This method is used to design Asphaltic Concrete (Asphalt-Rubber) [AR-AC] mixes using 4-inch diameter Marshall apparatus.

(b)   This test method involves hazardous material, operations, and equipment. This test method does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

(c)   See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

APPARATUS

2.   This test method is used in conjunction with the test methods listed below. Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual. The required apparatus is shown in the individual test methods, as appropriate.

ARIZ 201	Sieving of Coarse and Fine Graded Soils and Aggregates
ARIZ 205	Composite Grading
ARIZ 210	Specific Gravity and Absorption of Coarse Aggregate
ARIZ 211	Specific Gravity and Absorption of Fine Aggregate
ARIZ 212	Percentage of Fractured Coarse Aggregate Particles
ARIZ 238	Percent Carbonates in Aggregate
ARIZ 247	Particle Shape and Texture of Fine Aggregate Using Uncompacted Void Content
ARIZ 410	Compaction and Testing of Bituminous Mixtures Utilizing 101.6 mm (Four-Inch) Marshall Apparatus

ARIZ 415   Bulk Specific Gravity and Bulk Density of Compacted Bituminous Mixtures

ARIZ 416   Preparing and Splitting Field Samples of Bituminous Mixtures for Testing

ARIZ 806   Maximum Theoretical Specific Gravity of Laboratory Prepared Bituminous Mixtures (Rice Test)

AASHTO T 96   Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

AASHTO T 176   Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

AASHTO T 228   Specific Gravity of Semi-Solid Bituminous Materials

MATERIALS

3.   (a)   Mineral Aggregate - The mineral aggregate used in the design shall be produced material from the source(s) for the project. Use of natural sand is not permitted in AR-AC mixtures.

    1)   Mineral aggregate from each source shall be tested for compliance to the project requirements for Abrasion (AASHTO T 96).

    2)   The composited gradation of the aggregate and the composited gradation of the aggregate-mineral admixture blend shall comply with the grading limits of the specifications.

    3)   The composited mineral aggregate shall conform to the requirements of the specifications for Sand Equivalent (AASHTO T 176), Fractured Coarse Aggregate Particles (ARIZ 212), Uncompacted Void Content (ARIZ 247), and Percent Carbonates (ARIZ 238) when applicable.

    (b)   Bituminous Material - The bituminous material used in the design shall be asphalt-rubber material [hereinafter Crumb Rubber Asphalt (CRA)], conforming to the requirements of Section 1009 of the specifications, which is to be used in the production of the AR-AC. The specific gravity of the CRA and of the asphalt cement used in the CRA shall be determined in accordance with AASHTO T 228.

    (c)   Mineral Admixture - Mineral admixture is required. The mineral admixture used in the design shall be the same type of material to be used in production of the AR-AC. The mineral admixture shall conform to the requirements of the specifications.

DETERMINATION OF COMPOSITE GRADATION

4. (a) The gradation of the aggregate from each individual component stockpile or bin shall be determined in accordance with ARIZ 248 using washed sieve analysis Alternate #4 or Alternate #5. For alternate #5, washing of the coarse aggregate may be performed on the composite Plus No. 4 material and applied to the composite percent pass the minus No. 200 determined from the unwashed coarse sieving and washed fine sieving of the individual stockpiles.

(b) The composite gradation of the mineral aggregate is determined using desired percentages of each component based on washed sieve analysis. Mix designs may be developed based on bin or stockpile material, as appropriate for the respective mix production facility to be used.

(c) The mineral aggregate composite shall be determined in accordance with ARIZ 205.

(d) The aggregate-mineral admixture blend composite is determined by adjusting the mineral aggregate composite (percent passing) for mineral admixture by performing the calculation in Equation 1 for each sieve:

$$Equation\ 1: \begin{pmatrix} \% \text{ passing} \\ \text{each sieve} \\ \text{[Adjusted for} \\ \text{Mineral} \\ \text{Admixture]} \end{pmatrix} = \frac{\begin{pmatrix} \% \text{ passing} \\ \text{each sieve in} \\ \text{the aggregate} \\ \text{composite} \end{pmatrix} + \begin{pmatrix} \% \text{ Mineral} \\ \text{Admixture} \end{pmatrix}}{(100) + (\% \text{ Mineral Admixture})} \times 100$$

(e) The composited gradation of the aggregate and the composited gradation of the aggregate-mineral admixture blend shall be shown on the design report, along with the percentage of each material.

PREPARING AGGREGATE SAMPLES FOR MIX DESIGN TESTING

5. Based on the stockpile or bin composite aggregate gradation, the aggregate samples needed for mix design tests are prepared as follows.

(a) Representative samples of material which are retained on the individual No. 8 and larger sieve sizes and the minus No. 8 material from each stockpile or bin are used to prepare the aggregate samples for mix design testing.

(b)   Table 1 shows the aggregate sample sizes, the number of samples required for each test listed, and which samples include mineral admixture.   The aggregate weight shown for Maximum Theoretical Specific Gravity will provide 3 Rice test specimens and the amount shown for Density-Stability/Flow will produce 3 Marshall specimens.

Table 1		
Test	**Sample Size**	**Number of Samples**
Fine Aggregate Specific Gravity/ Absorption (ARIZ 211)	1200 grams of Mineral Aggregate [No mineral admixture]	1
Coarse Aggregate Specific Gravity/Absorption (ARIZ 210)	2000 grams of Mineral Aggregate [No mineral admixture]	1
Maximum Theoretical Specific Gravity (Rice Test) (ARIZ 806, as modified in Section 10)	3000 grams of Mineral Aggregate [Plus 30 grams of mineral admixture]	1 [Yields 3 test specimens]
Density-Stability/Flow (ARIZ 415 and ARIZ 410, as modified in Sections 8 and 9 respectively)	3000 grams of Mineral Aggregate (See Note 1) [Plus 30 grams of mineral admixture]	3 (See Note 2) [Each sample yields 1 set of 3 Marshall Specimens]
Note 1: Generally 3000 grams of mineral aggregate will provide specimens of acceptable heights, but adjustments may be necessary in some cases. Use Equation 2 to adjust aggregate weights as necessary to conform to specimen height requirements of 2.50 ± 0.20 inches. $$\text{\emph{Equation 2}: Adjusted Wt. of Aggregate} = \frac{\left(\dfrac{\text{Combined Bulk O.D.}}{\text{Agg. Specific Gravity}}\right)}{2.650} \text{ x } 3000$$		
Note 2: Requires one (1) sample for each CRA binder content to be tested (minimum of 3 contents, with 3 Marshall specimens at each content).		

(c)   After the aggregate samples for the Rice and Marshall specimens have been composited, add 1% mineral admixture by weight of the aggregate, and mix thoroughly. Add 3% water by dry weight to each sample and mix thoroughly to wet the mineral admixture and aggregate surfaces. After mixing, dry to constant weight in accordance with paragraph 7(a).

AGGREGATE SPECIFIC GRAVITIES AND ABSORPTION

6.   Determine the Bulk Oven Dry, S.S.D., Apparent Specific Gravities and Absorption for the fine aggregate (Minus No. 4) and the coarse aggregate (Plus No. 4) in accordance with ARIZ 211 and ARIZ 210 respectively.

(a)   Using Equation 3, calculate the Combined Bulk Oven Dry (Gsb), S.S.D., and Apparent Specific Gravities of the aggregate-mineral admixture blend.

$$\textit{Equation 3:} \quad \begin{pmatrix} \text{Combined Specific Gravity} \\ \text{of Aggregate and Mineral} \\ \text{Admixture Blend} \end{pmatrix} = \frac{P_c + P_f + P_{admix}}{\dfrac{P_c}{G_c} + \dfrac{P_f}{G_f} + \dfrac{P_{admix}}{G_{admix}}}$$

Where:
- P_c, P_f = Weight percent of coarse aggregate and fine aggregate respectively. Determined from the aggregate composite without mineral admixture.
- P_{admix} = Percent mineral admixture by weight of the aggregate.
- $P_c + P_f$ = 100
- $P_c + P_f + P_{admix}$ = 100 + % Mineral Admixture
- G_c, G_f = Specific gravity of the coarse and the fine aggregate respectively.
- G_{admix} = Specific gravity of the mineral admixture.
  - Type II Cement = 3.14
  - Type IP Cement = 3.00
  - Hydrated Lime   = 2.20

(b)   Using Equation 4, calculate the Combined Absorption of the aggregate-mineral admixture blend.

$$\textit{Equation 4:} \quad \begin{pmatrix} \text{Combined Absorption} \\ \text{of Aggregate and Mineral} \\ \text{Admixture Blend} \end{pmatrix} = \frac{(P_c \times A_c) + (P_f \times A_f) + (P_{admix} \times A_{admix})}{P_c + P_f + P_{admix}}$$

Where: P_c, P_f = Weight percent of coarse aggregate
and fine aggregate respectively.
Determined from the aggregate composite
without mineral admixture.

P_{admix} = Percent mineral admixture by weight
of the aggregate.

$P_c + P_f$ = 100

$P_c + P_f + P_{admix}$ = 100 + % Mineral Admixture

A_c, A_f = Percent water absorption of the coarse
aggregate and the fine aggregate
respectively.

A_{admix} = Percent water absorption of mineral
admixture (<u>assumed to be 0.0%</u>).

PREPARATION OF SPECIMENS FOR DENSITY AND MARSHALL STABILITY/FLOW DETERMINATION

7.   Marshall specimens shall be prepared as follows.

NOTE: Normally a range of 3 different CRA binder contents at 1.0% increments will provide sufficient information, although in some cases it may be necessary to prepare additional sets of samples at other CRA binder contents. Two series of CRA binder contents are customarily used: either 6.0, 7.0, and 8.0% CRA by total mix weight; or 6.5, 7.5, and 8.5% CRA by total mix weight.

NOTE: Although a wide range of mixers may provide the desired well-coated homogeneous mixture, commercial potato mashers or dough mixers with whips are often used. Minimum recommended capacity of the mixing bowl is 10 quarts.

(a)   The aggregate-mineral admixture blend shall be dried to constant weight at 325 ± 3 °F and shall be at this temperature at the time of mixing with the CRA. If necessary, a small amount of proportioned Pass No. 8 aggregate make-up material shall be added to bring samples to the desired weight.

(b)   Before each batch of AR-AC is mixed, the CRA shall be heated in a loosely covered container in a forced draft oven for approximately 2 hours or as necessary to reach a temperature of 330 ± 5 ⁰F. Upon removal from the oven, the CRA shall be thoroughly stirred using a stiff-bladed flat spatula with blade approximately 1-inch wide, 1/8-inch thick, and long enough to reach the bottom of the container. (As an alternate to a stiff-bladed spatula, flat bar stock meeting the dimensional requirements may be used.) Use combined circular, vertical, and radial stirring motions to uniformly distribute the rubber particles throughout the CRA before adding the designated proportion to the aggregate-mineral admixture blend. If there is any delay before beginning of mixing the CRA with the aggregate-mineral admixture blend, thoroughly stir the CRA again immediately before pouring.

> ***CAUTION: To avoid damage to the CRA, do not use a hot plate or open flame to bring it to temperature. Once the CRA temperature has reached 330 ± 5 ⁰F, the container may briefly be moved to a hot plate for no more than 5 minutes to maintain temperature. If a hot plate is utilized, the CRA shall be constantly stirred to avoid sticking or scorching. Do not heat the CRA longer than necessary to complete batching and mixing operations (approximately three hours total heating time), or damage may occur.***

> NOTE: Before each batch is mixed, the mixing bowl and whip shall be heated to 325 ± 3 ⁰F, and the weight of CRA required to provide the desired content shall be calculated.

(c)   The aggregate-mineral admixture blend and the appropriate amount of CRA shall be mixed together as quickly as possible in order to maintain the required mixing temperature of 325 ± 3 ⁰F while producing a well-coated homogeneous AR-AC mixture. **Mechanical mixing is required.**

> NOTE: After mechanical mixing, hand mixing may be used as needed to obtain more thorough coating of the aggregate.

(d)   Immediately after mixing, each batch of AR-AC shall be placed on a tarp or sheet of heavy paper and in a rolling motion thoroughly mixed and spread according to the procedures described in ARIZ 416. The circular mass shall be cut into 6 equal pie-shaped segments. Take opposite segments for each individual specimen and use up the entire batch.

(e)   Each AR-AC specimen shall be spread in a large pan at nominal single-stone thickness. Avoid stacking particles as feasible. Allow specimen to cure for 2 hours ± 10 minutes at 300 ± 5 °F.

(f)   A mold assembly (base plate, mold, and collar) shall be heated to approximately 325 ± 3 °F. The face of the compaction hammer shall be thoroughly cleaned and heated on a hot plate set at 325 ± 3 °F.

(g)   Place a 4-inch diameter paper disc in the bottom of the mold before the mixture is introduced. Place the entire specimen in the mold with a heated spoon. Spade the mixture vigorously with a heated flat metal spatula, with a blade approximately 1-inch wide and 6-inches long and stiff enough to penetrate the entire layer of material, 15 times around the perimeter and 10 times at random into the mixture, penetrating the mixture to the bottom of the mold.   Smooth the surface of mix to a slightly rounded shape.

> NOTE: To ease removal of the end papers after compaction, they may be sprayed with a light application of aerosol based vegetable oil. PAM brand cooking spray has been found to work well for this application.

(h)   Before compaction, put the mold containing the AR-AC specimen in an oven for approximately one hour or as needed to heat the mixture specimen to the proper compaction temperature of 325 ± 3 °F.

(i)   Immediately upon removing the mold assembly loaded with mix from the oven, place a paper disc on top of mixture, place the mold assembly on the compaction pedestal in the mold holder, and apply 75 blows with the compaction hammer. Remove the base plate and collar, and reverse and reassemble the mold. Apply 75 compaction blows to the face of the reversed specimen.

> NOTE: The compaction hammer shall apply only one blow after each fall, that is, there shall not be a rebound impact. The compaction hammer shall meet the requirements specified in Section 2(c) of ARIZ 410.

(j)   Remove the collar and top paper disc. Remove the base plate and remove the bottom paper disc while the specimen is still hot. Replace the base plate immediately, making sure to keep the mold and specimen oriented so that the bottom face of the compacted specimen remains directly in contact with, and is fully supported by, the base plate.

> NOTE: Paper discs need to be removed while the AR-AC specimen is hot. The discs are very difficult to remove after the specimens have cooled.

(k)   If any part of the top surface of a compacted specimen is visually observed to increase in height (rise or swell in the mold) after compaction, stop testing and discard the prepared specimens. Adjust the gradation of the aggregate-mineral admixture blend to provide additional void space to accommodate the CRA, then batch and compact new trial AR-AC specimens. If no visible increase in height occurs, proceed with paragraphs 7(l) through 7(o).

(l)   Allow each compacted specimen to cool in a vertical position in the mold (with the base plate on the bottom and the top surface exposed to air) until they are cool enough to be extruded without damaging the specimen. Rotate the base plate occasionally to prevent sticking.

> NOTE: Generally specimens can be extruded without damage when they are at a temperature of approximately 77 to 90 °F.

> NOTE: Cooling may be accomplished at room temperature, or in a 77 °F air bath. If more rapid cooling is desired, the mold and specimen may be placed in front of a fan until cool, ***but do not turn the mold on its side***.

(m)   Orienting the mold and specimen so that the ram pushes on the bottom face (base plate face) of the specimen, extrude the specimen.

> NOTE: Care shall be taken in extruding the specimen from the mold, so as not to deform or damage the specimen. If any specimen is deformed or damaged during extrusion, the entire set of specimens at that CRA binder content shall be discarded and a new set prepared.

(n)   Immediately upon extrusion, measure and record the height of the specimen to the nearest 0.001 inch and determine and record its weight in air to the nearest 0.1 gram.

> NOTE: Compacted AR-AC specimens shall be 2.50 ± 0.20 inches in height. If this criteria is not met for the specimens at each CRA binder content, the entire set of specimens at that CRA binder content shall be discarded and a new set prepared after necessary adjustments in the aggregate weight have been made using Equation 2 (see Note 1 in Table 1).

(o)   Repeat the procedures in paragraphs 7(e) through 7(n) for the required specimens.

BULK SPECIFIC GRAVITY/BULK DENSITY OF SPECIMENS

8. (a) Determine the bulk specific gravity of the three compacted AR-AC specimens at each CRA binder content in accordance with ARIZ 415, Method A, except that the paraffin method shall not be used. The determination of the "Weight in Water" and "S.S.D. Weight" of each specimen will be completed before the next specimen is submerged for its "Weight in Water" determination.

> NOTE: Specimens fabricated in the laboratory that have not been exposed to moisture do not require drying after extrusion from the molds. The specimen weight in air obtained in paragraph 8(a) is its dry weight.

(b) Determine the density in pounds per cubic foot (pcf) by multiplying the specific gravity of each specimen by 62.3 pcf.

> NOTE: For each CRA binder content, the densities of individual compacted specimens shall not differ by more than 2.0 pcf. If this density requirement is not met, the entire set of specimens at that CRA binder content shall be discarded and a new set of specimens prepared.

(c) Determine the average bulk specific gravity (G_{mb}) and/or average bulk density values for each CRA binder content and plot on a separate graph versus CRA binder content. Connect the plotted points with a smooth curve that provides the "best fit" for all values as shown in Figure 1.

STABILITY AND FLOW DETERMINATION

9. The stability, stability corrected for height, and flow of each specimen shall be determined according to ARIZ 410. (Stability and stability corrected for height are recorded to the nearest 10 pounds, and flow is recorded to the nearest 0.01 inch.)

(a) Determine and record the average values for stability corrected for height (to the nearest 10 pounds) and flow (to the nearest 0.01 inch) for each CRA binder content, and plot each on a separate graph using the same scale for CRA binder content as used in 8(c). Connect the plotted points with a smooth curve that provides the "best fit" for all values as shown in Figure 1.

> NOTE: Flow values may be high compared to conventional asphaltic concrete mixtures.

MAXIMUM THEORETICAL SPECIFIC GRAVITY (RICE TEST)

10. The maximum theoretical specific gravity of the mixture shall be determined in accordance with ARIZ 806 at 6.0% CRA binder content with the following modifications.

(a) Prepare the AR-AC specimens including mineral admixture according to the procedures described in Section 5 and paragraphs 7(a) through 7(c) using 6.0% CRA by total mix weight. A liquid anti-stripping agent is not used.

(b) Spread the entire Rice sample in a large pan at nominal single-stone thickness. Avoid stacking particles as feasible.

(c) Oven cure the entire Rice sample for 2 hours ± 10 minutes at 300 ± 5 ºF.

(d) Immediately upon removal from the oven, place the sample on a tarp or sheet of paper and break up fine particle agglomerations. Then, in a rolling motion thoroughly mix and spread the sample according to the procedures described in ARIZ 416. The circular mass shall be cut into 6 equal pie-shaped segments. Take opposite segments for each individual test sample and use up the entire batch.

(e) Using Equation 5, calculate the effective specific gravity of the aggregate-mineral admixture blend (G_{se}).

$$\textit{Equation 5:} \qquad G_{se} = \frac{100 - P_{br}}{\dfrac{100}{G_{mm}} - \dfrac{P_{br}}{G_b}}$$

Where:
G_{se} = Effective specific gravity of the aggregate-mineral admixture blend.
G_{mm} = Maximum theoretical specifc gravity of the AR-AC at CRA binder content P_{br}.
P_{br} = CRA binder content at which the Rice test was performed.
G_b = Specific gravity of the CRA.

(f) Using Equation 6, calculate the maximum theoretical specific gravity (G_{mm}) for different CRA binder contents.

NOTE: G_{se} is considered constant regardless of binder content.

$$\textit{Equation 6:} \qquad G_{mm} = \frac{100}{\dfrac{P_s}{G_{se}} + \dfrac{P_b}{G_b}}$$

Where: G_{mm} =   Maximum theoretical specific gravity
of the AR-AC at CRA binder content P_b.

P_s =   Aggregate and mineral admixture content,
percent by total weight of mix (100-P_b).

P_b =   CRA binder content, percent by total weight
of mix.

G_{se} =   Effective specific gravity of the
aggregate-mineral admixture blend.

G_b =   Specific gravity of the CRA.

DETERMINATION OF DESIGN CRA BINDER CONTENT

11.   The design CRA binder content is determined as follows in paragraphs 11(a) through 11(e).

(a)   For each CRA binder content used, calculate effective voids (V_a), percent absorbed CRA (P_{ba}), voids in mineral aggregate (VMA), and voids filled with CRA (VFA) using the following equations.

1) Using Equation 7, calculate the effective voids (V_a). The calculated G_{mm} values for the respective CRA binder contents are used to determine the corresponding effective voids content of the compacted Marshall specimens at each CRA binder content level.

$$\textit{Equation 7:} \qquad V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}} \right) \times 100$$

Where: V_a =   Effective voids in the compacted
mixture, percent of total volume.

G_{mm} =   Maximum theoretical specifc gravity
of the AC-AR at CRA binder content P_b.

G_{mb} =   Bulk specific gravity of compacted
mixture specimens.

2) Using Equation 8, calculate the percent absorbed CRA (P_{ba}).

Equation 8: $\qquad P_{ba} = \left(\dfrac{G_{se} - G_{sb}}{G_{sb} \ x \ G_{se}} \right) x \ G_b \ x \ 100$

Where: $\quad P_{ba}$ = Absorbed CRA, percent by total
weight of mix.
G_{se} = Effective specific gravity of the
aggregate-mineral admixture blend.
G_b = Specific gravity of the CRA.
G_{sb} = Bulk oven dry specific gravity of the
aggregate-mineral admixture blend.

   3) Using Equation 9, calculate voids in mineral aggregate (VMA).

Equation 9: $\qquad VMA = 100 - \left(\dfrac{G_{mb} \ x \ P_s}{G_{sb}} \right)$

Where: VMA = Voids in the mineral aggregate,
percent of bulk volume.
G_{sb} = Bulk oven dry specific gravity of the
aggregate-mineral admixture blend.
G_{mb} = Bulk specific gravity of compacted
mixture specimens.
P_s = Aggregate and mineral admixture content,
percent by total weight of mix ($100 - P_b$).

   4) Using Equation 10, calculate voids filled with CRA (VFA).

Equation 10: $\qquad VFA = \left(\dfrac{VMA - V_a}{VMA} \right) x \ 100$

Where: VFA = Voids filled with CRA.
VMA = Voids in the mineral aggregate,
percent of bulk volume.
V_a = Effective voids in the compacted
mixture, percent of total volume.

      (b) Using a separate graph for each of the volumetric properties calculated in paragraph 11(a), plot the average value for each set of three specimens versus CRA binder content. Connect the plotted points with a smooth curve that provides the "best fit" for all values as shown in Figure 1.

NOTE: The percentage of absorbed CRA (P_{ba}) and the effective specific gravity of the aggregate-mineral admixture blend (G_{se}) do not vary with CRA binder content.

(c) The design CRA binder content shall be the CRA binder content which meets the Mix Design Criteria requirements of the specifications, and provides effective voids as close as possible to the middle of the specified range.

(d) Use the effective voids (V_a) plot or interpolation to select the CRA binder content that yields the target effective voids content in the specifications. Use interpolation or the other plots to determine the values of bulk specific gravity (G_{mb}) and/or bulk density, VMA, VFA, stability and flow that correspond to the selected CRA binder content, and compare these with the limits in the specifications. Properties for which limits are not specified are evaluated by the Engineer for information only.

(e) If it is not possible to obtain specification compliance within the range of CRA binder contents used, a determination must be made to either redesign the mix (different aggregate gradation or source) or prepare additional specimens at other CRA binder contents for bulk specific gravity (G_{mb}) and/or bulk density, stability/flow testing, and volumetric analyses.

(f) Using Equation 6, calculate the maximum theoretical specific gravity (G_{mm}) for the design CRA design content. The maximum theoretical density is determined by multiplying the calculated G_{mm} by 62.3 pounds per cubic foot.

(g) For information, calculate the following volumetric properties at the design CRA binder content.

1) Using Equation 11, calculate the percent effective CRA binder content (P_{be}) of the AR-AC mixture.

$$\text{Equation 11:} \qquad P_{be} = P_b - \left(\frac{P_{ba} \times P_s}{100} \right)$$

Where: P_{be} = Percent effective CRA binder content of the mixture (free binder not absorbed).

P_b = CRA binder content, percent by total weight of mix.

P_{ba} = Absorbed CRA, percent by total weight of mix.

P_s = Aggregate and mineral admixture content, percent by total weight of mix ($100 - P_b$).

2) Using Equation 12, calculate the effective CRA volume (V_{be}).

Equation 12:
$$V_{be} = \frac{P_{be} \times G_{mb}}{G_b}$$

Where: V_{be} = Effective CRA volume, percent
of bulk volume.

P_{be} = Percent effective CRA binder content of
the mixture (free binder not absorbed).

G_{mb} = Bulk specific gravity of compacted
mixture specimens.

G_b = Specific gravity of the CRA.

MIX DESIGN GRADATION TARGET VALUES

12.   The desired target values for the aggregate composite and the aggregate-mineral admixture blend composite in the AR-AC mixture shall be from the composited gradation and shall be expressed as percent passing particular sieve sizes as required by the specifications for the project.

REPORT

13.   Report the test results and data obtained on the appropriate form. Liberal use of the remarks area to clarify and/or emphasize any element of the design is strongly recommended. Information required in the mix design report includes:

(a)   Aggregate and Mineral Admixture:
1)   Aggregate source and identification
2)   Individual aggregate stockpile or bin gradations
3)   Mineral admixture type, source, and specific gravity
4)   Aggregate blend proportions and composite gradation for the mix design, with and without mineral admixture
5)   Fine and coarse aggregate specific gravities (Bulk Oven Dry, SSD, Apparent) and absorption
6)   Combined specific gravities [Bulk Oven Dry (G_{sb}), SSD, Apparent] and absorption of the aggregate-mineral admixture blend
7)   Aggregate quality
a)   LA Abrasion
b)   Sand Equivalent
c)   Fractured Coarse Aggregate Particles (Percentage with one fractured face and percentage with two fractured faces)

                d)   Uncompacted Void Content

                e)   Carbonates (When applicable)

(b)   CRA Binder Design (from supplier), including:

      1)   Source and grade of base asphalt cement

      2)   Source and type of crumb rubber

      3)   Crumb rubber gradation

      4)   Proportions of asphalt cement and crumb rubber

      5)   CRA binder properties, in compliance with Section 1009 of the ADOT Specifications

      6)   CRA specific gravity (G_b)

      7)   Asphalt cement specific gravity

(c)   Maximum theoretical specific gravity (G_{mm}) and density (pcf) at the CRA binder content at which the Rice test was performed (P_{br})

(d)   Mixture Compaction Trials:

      1)   CRA binder content (P_b)

      2)   Aggregate and mineral admixture content (P_s)

      3)   Calculated maximum theoretical specific gravity (G_{mm}) and density (pcf)

      4)   Bulk specific gravity (G_{mb}) and bulk density (pcf) of Marshall specimens

      5)   Percent effective voids (V_a)

      6)   Percent voids in mineral aggregate (VMA)

      7)   Percent air voids filled (VFA)

      8)   Percent absorbed CRA (P_{ba})

      9)   Effective specific gravity of the aggregate-mineral admixture blend (G_{se})

      10)   Effective CRA binder contents (P_{be}) and volumes (V_{be})

      11)   Marshall stability (nearest 10 pounds)

      12)   Marshall flow (0.01 inch)

(e)   Plots of the following properties versus CRA binder content:

      1)   Percent effective voids (V_a)

      2)   Percent voids in mineral aggregate (VMA)

      3)   Percent air voids filled (VFA)

      4)   Bulk specific gravity (G_{mb}) and/or bulk density

      5)   Marshall stability

      6)   Marshall flow

(f)   Final Design:

      1)   CRA binder content (P_b)

      2)   Calculated maximum theoretical specific gravity (G_{mm}) and density (pcf)

      3)   Bulk specific gravity (G_{mb}) and bulk density (pcf) of Marshall specimens

      4)   Percent effective voids (V_a)

5) Percent voids in mineral aggregate (VMA)
6) Percent air voids filled (VFA)
7) Percent absorbed CRA (P_{ba})
8) Effective specific gravity of the aggregate-mineral admixture blend (G_{se})
9) Effective CRA binder contents (P_{be}) and volumes (V_{be})
10) Marshall stability (nearest 10 pounds)
11) Marshall flow (0.01 inch)
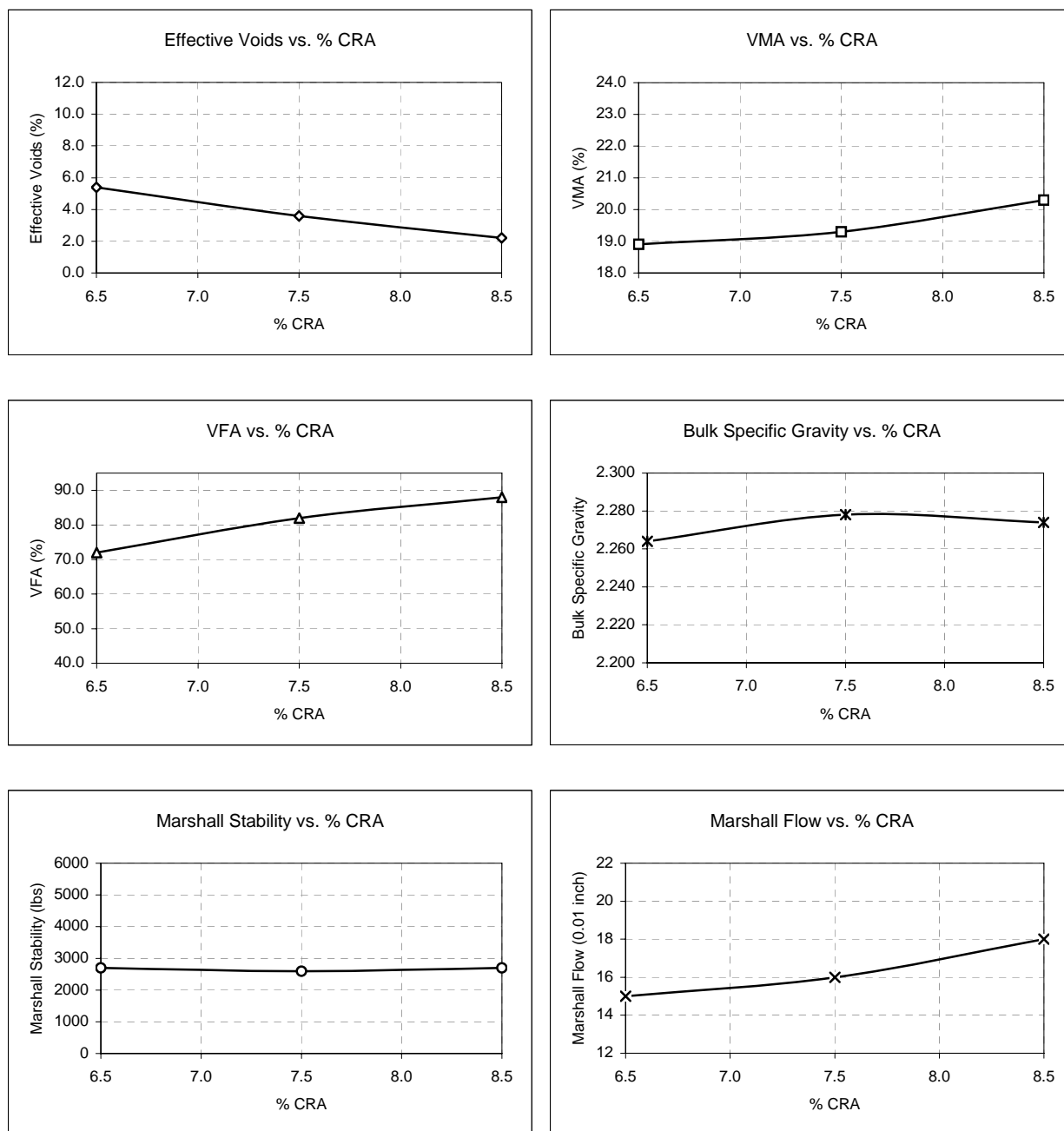
Example Plots of Effective Voids, VMA, VFA, Bulk Specific Gravity, Marshall Stability, and Marshall Flow versus CRA Binder Content

FIGURE 1